AD-A086 118 FEDERAL AVIATION ADMINISTRATION WASHINGTON DC OFFICE --ETC F/G 17/7
A METHOD FOR ADMINISTRATIVE ASSIGNMENT OF RUNWAY SLOTS.(U)
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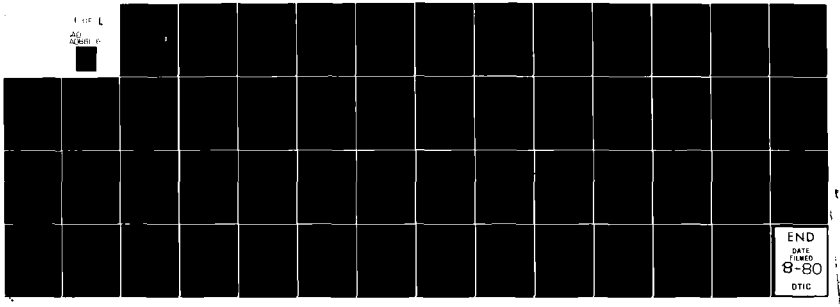

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Federal Aviation Administration

A Method for Administrative Assignment of Runway Slots

Office of Aviation Policy
Washington, D.C. 20590

FAA-AVP-80-5

June 1980

Kenneth E. Geisinger

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-AVP-80-5	AD-A086 118	

4. Title and Subtitle	5. Report Date
A Method for Administrative Assignment of Runway Slots.	June 1980
	6. Performing Organization Code: AVP-210
7. Author(s): Kenneth E. Geisinger	8. Performing Organization Report No.: FAA-AVP-80-5
9. Performing Organization Name and Address: Office of Aviation Policy, Federal Aviation Administration, Washington, D. C. 20591	10. Work Unit No. (TRAIS)
	11. Contract or Grant No.
12. Sponsoring Agency Name and Address: Same	13. Type of Report and Period Covered: Final
	14. Sponsoring Agency Code: AVP-210

15. Supplementary Notes

None

16. Abstract

Federal Aviation Regulations set quotas (upper limits) on the number of operations per hour at each of four major U.S. air carrier airports: Washington National, New York LaGuardia, Chicago O'Hare International and New York Kennedy International. The reservation for one of these operations is referred to as a "runway slot".

The runway slots designated for scheduled air carriers are periodically assigned to the various carriers in advance and airline schedules are built around them. How many slots each airline gets is determined by mutual agreement among the airlines through airline scheduling committees. These committees might be abolished and their function might have to be performed by the Federal Aviation Administration (FAA).

This report presents a method for administratively assigning slots to the airlines. It is based on observations made of the scheduling committees. The major difference is that in the scheduling committees, decisions are made in order to get unanimous consent; in the administrative procedure, decisions are made to maximize a measure of passenger service.

17. Key Words	18. Distribution Statement
Airport, Capacity, Assignment, Allocation, Slot, Runways, Schedules	Document is available to the public through the National Technical Information Service, Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	50	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

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A METHOD FOR ADMINISTRATIVE ASSIGNMENT OF AIRPORT RUNWAY SLOTS

ABSTRACT

Federal Aviation Regulations set quotas (upper limits) on the number of operations per hour at each of four major U.S. air carrier airports: Washington National, New York LaGuardia, Chicago O'Hare International and New York Kennedy International. The reservation for one of these operations is referred to as a "runway slot."

The runway slots designated for scheduled air carriers are periodically assigned to the various carriers in advance and airline schedules are built around them. How many slots each airline gets is determined by mutual agreement among the airlines through airline scheduling committees. These committees might be abolished and their function might have to be performed by the Federal Aviation Administration (FAA).

This report presents a method for administratively assigning slots to the airlines. It is based on observations made of the scheduling committees. The major difference is that the committee decisions are made in order to reach unanimous consent while the objective of this procedure is to optimize service to the flying public.

The proposed methodology consists of two stages:

1. The allocation of slots for the day between airlines.
2. The assignment of a number of slots each hour to each airline.

The allocation is based on three factors:

1. The current allocation is used as the starting point of the computations. The number of slots currently held is recognized as an investment by the airline in developing and providing service for particular markets.
2. The number of passengers enplaned or deplaned per slot is a measure of passenger service efficiency based on volume. It tends to favor large aircraft used on high-density market routes.
3. The number of locations served divided by the number of slots an airline has is a measure of breadth of service. It tends to favor carriers with small aircraft serving a number of small communities with a few slots.

Based on these considerations and the number of slots requested by each airline, the number of slots allocated to each airline is determined.

The assignment of slots by hour is based on alternative slot plans submitted by each airline. Each airline is required to submit a number of alternative plans, each with an associated value indicating the preference of the airline. If possible, each airline is assigned slots according to one of the plans it has submitted. The selection is made such that:

1. The total slots assigned each hour does not exceed the quota.

2. The total slots assigned to each airline does not exceed the airline's allocation.

3. The combination of plans selected maximizes a function that considers the airline preferences.

This report also includes sample problems and an analysis of the results.

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SECTION I

INTRODUCTION

BACKGROUND

Federal Aviation Regulations designate an upper limit (quota) on the number of operations (takeoffs or landings) per hour at four major U.S. airports: Washington National (DCA), New York LaGuardia (LGA), New York Kennedy International (JFK) and Chicago O'Hare International (ORD). The quotas apply only to instrument flight rules operations. During good visibility conditions, operations (particularly, non-scheduled operations) can exceed the quota. The quota rules are summarized in Table 1-1.

The use of the runways for one operation is referred to as a "runway slot." The runway slots designated for scheduled air carriers are assigned to the various carriers in advance and airline schedules are built around them. How many slots each airline gets for each hour at each airport is determined by mutual agreement between the airlines through Airline Scheduling Committees. These committees, which consist of one representative of each of the airlines serving a particular airport, were established when the quotas were put into effect in 1969. They were granted a special exemption to the anti-trust regulations by the Civil Aeronautics Board (CAB).

With the advent of airline deregulation, the possibility that the committees inhibit airline competition has been suggested and the CAB and Department of Justice (DOJ) are currently questioning if these exemptions should be continued. If the committees are abolished, their functions might have to be performed by some governmental authority such as the Federal Aviation Administration (FAA).

OBJECTIVE

This report presents an administrative assignment technique that was designed to both maximize passenger service and consider the airlines' constraints and requirements to the maximum extent possible. It was based on observations made of the current procedures.

Table 1-1

Quota Rules

Class of User	Instrument Flight Rules Operations Per Hour			
	Washington National	New York LaGuardia	New York JFK	Chicago O'Hare
Certificated Air Carrier	40	48	70/80[1/]	115
Scheduled Air Taxi/Commuter	8	6	5	10
Other	12	6	5	10
Total	60[2/3/]	60[3/]	80/90	135[3/]
Hours in force	All day	All day	3-8 pm	3-8 pm

Notes:

1. 70 per hour between 3 and 5 pm, 80 per hour between 5 and 9 pm
2. Does not include charter flights or other non-scheduled flights of scheduled or supplemental air carriers
3. Does not include extra sections of scheduled air carrier flights

Source: Code of Federal Regulations, Title 14, Part 93, Sub-part K

CURRENT PROCEDURES - CERTIFICATED AIR CARRIERS

The following is a brief summary of the current procedures for assignment of slots to certificated air carriers:

1. Airline scheduling committees meet twice a year: in July to assign slots for the winter schedule, and in January to assign slots for the summer schedule. A separate committee meets for each airport. Additional meetings are called when needed.

2. The airlines submit a request for the number of slots desired each hour of each day of the week at each airport to the Reservation Center about one month prior to the meeting. The Reservation Center handles all of the bookkeeping involved in the process, during and between meetings.

3. At the meetings initial requests are whittled down by voluntary concessions from the participating airlines until the quota levels are reached. The committee concentrates on one particular day (when requests are maximum). Other days (different days of the week or different weeks) then generally fall into place. The first step is to get the requests down to where the total slots requested does not exceed the total available. The second step is to get the airlines to "slide" their submission so that the number requested does not exceed the quota in any hour.

4. Some airports are easy to resolve (e.g., JFK) and some are difficult to resolve (e.g., Washington National). The committees meet in sequence beginning with the airport most difficult to resolve and ending with the airport that is the least difficult to resolve. Airlines are permitted to turn in slots that they cannot use and they are given to other airlines on a first come-first served basis.

CURRENT PROCEDURES - COMMUTERS

The slot allocation to commuter airlines is currently on a first-come-first served basis. Changes are made only when a carrier wishes to give up a slot, in which case it is offered to the first carrier on the list. The commuter scheduling committee at National Airport is currently developing a procedure to assure that new entrants obtain first priority in receiving new slots as they become available.

ADMINISTRATIVE SLOT ALLOCATION PROCEDURE

Like the current procedure for certificated carriers, the procedure set forth in this report also handles one given day for a given airport at a time. It requires, as input, the number of slots requested in each hour by each airline. It also consists of two steps: 1) allocating a total for the day to each airline, and 2) assigning slots by hour to each airline. A schematic of the proposed procedure is shown in Figure 1-1.

Allocation of Slots

The allocation of slots to each airline is based on two factors: 1) the current allocation, and 2) passenger service provided per slot in the current allocation.

Consideration of the current allocation recognizes the investment that the airlines have made in developing existing markets and service capacity. It also prevents turbulence in schedules that could result from one scheduling period to another. The procedure described here will tend to change the historic division of slots gradually over time based on differences in passenger service.

Passenger Service

Passenger service can be defined in many ways. One measure is the average number of passengers enplaned (for departures) or deplaned (for arrivals) per operation. This measure of efficiency indicates how many passengers are served with each slot. Some advantages of this definition are:

1. These data are available (CAB Form 536) or could be provided by the airlines.

2. It is based on demonstrated passenger preference.

3. The operations with the highest service tend to be more profitable to the airlines and to the airport operator, except that stage length increases airline profitability but not necessarily passenger service.

4. It favors larger aircraft (more service per slot).

5. It fosters airline competition (more business means more slots).

This measure, if used alone, would favor large capacity aircraft on dense markets at the expense of service on less dense markets--in particular, the smaller communities. A second measure has been added that considers the number of different cities served by an

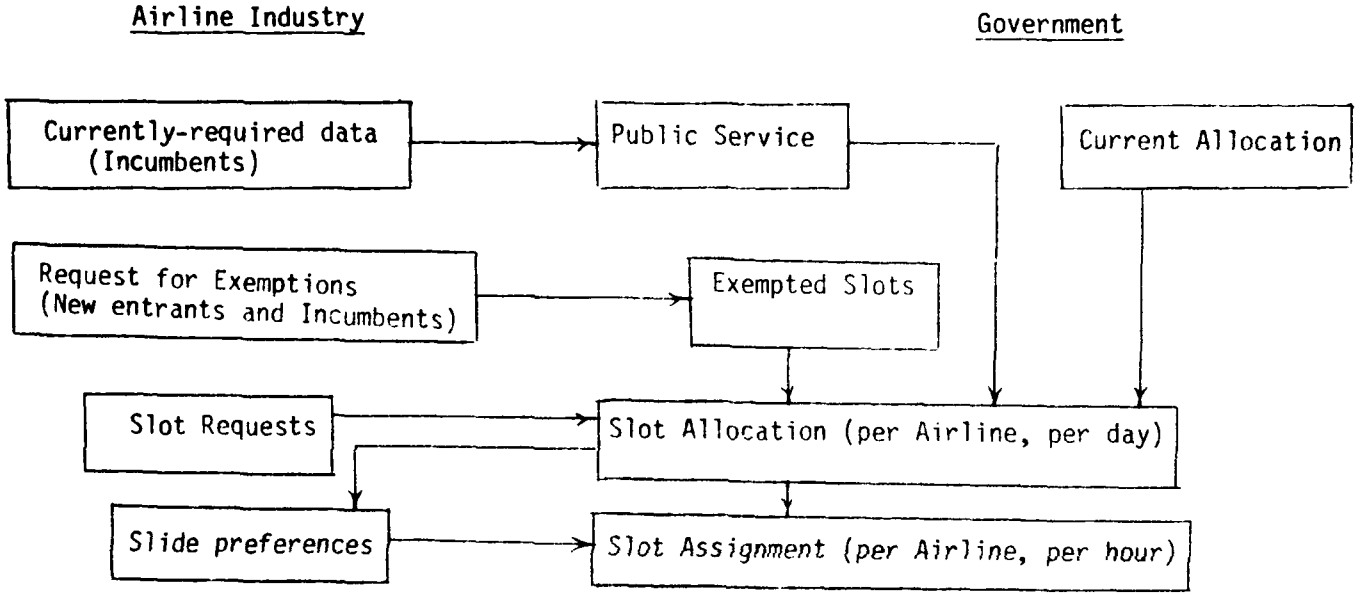

Figure 1-1 Schematic of Proposed Administrative Procedure

airline (breadth of service). The definition of this measure involves several issues which were resolved in view of keeping the measure simple and easy to compute.

1. Breadth of service is defined as the number of different locations served by the airline divided by the number of slots it has in its current schedule.

2. Only non-stop service to or from the airport in question is considered.

3. Each airport served is counted as a different location.

An argument in favor of the third rule is that different airports in the same major hub tend to serve different local communities (for example, Washington National and Baltimore Washington International) and where this is not the case, the airlines would be reluctant to set up duplicate service at more than one airport in the same hub because of the fixed costs involved.

If more than one airline serves the same location, each airline gets credit for that location as if it were the only airline serving it. A more sophisticated analysis would consider service as opposed to expected need, but this would be extremely cumbersome and questionable. The net effect, in the end, is to reward diversity of markets, which would be accomplished either way.

Combined Objectives

Increasing the number of passengers served per operation, increasing the number of locations served, and respecting historic shares of runway slots are somewhat contradictory goals. This procedure allows the balance between the three to be set by control variables. Setting these variables will require some experience and experimentation, and an executive decision.

The various elements are combined in one entitlement formula that, in simplified terms, resembles:

$$Zi = N \left[R(c_i/\Sigma c_i) + P(c_i e_i/\Sigma c_i e_i) + C(h_i/\Sigma h_i) \right]$$

Where:

Zi = Number of slots Airline i is entitled to
N = Number of slots to be awarded
ci = Current number of slots used by the airline
ei = Average enplanements and deplanement per operation
hi = Number of locations served from the airport
i = Index number identifying the airline
R, P, and C = Constant non-negative factors that sum to one

Three observations can be made from the above formula:

1. If all airlines serve the same number of passengers and locations per slot, the resultant allocation will be the same as the current allocation.

2. Each airline will receive at least R times its current allocation.

3. In general, the entitlement will be somewhere between these two extremes.

The actual allocation is a bit more complicated because: 1) some airlines will not request as many slots as they are entitled to, and 2) exempted slots (including new entrant slots) are included but are not shown here. When an airline is entitled to more slots than it requests, the excess slots are distributed among the other airlines that are entitled to fewer slots than they requested in proportion to their share of entitled slots. New entrants are given an initial allocation which is deducted from the portion of slots available above the number allocated from the current share. The details of this procedure are explained in Appendix A.

This procedure also has provision for special exemptions to permit slots to be allocated based on Government policy. Examples of this would be the honoring of international agreements made with foreign carriers and flights providing essential service to small communities. These must be considered on a case-by-case basis.

Assignment of Slots

The assignment of the slots to each airline by hour must observe two restrictions:

1. The number of slots assigned to an airline, summed over all hours, must not exceed the total number of slots allocated to the airline.

2. The number of slots assigned for each hour, summed over all airlines, must not exceed the quota for the hour.

In order to be practical, the assignment must consider the constraints that an actual scheduler faces: crew schedules, equipment availability, positioning of aircraft, passenger demand, gate availability, etc. To attempt to represent all of these conflicting considerations for each airline and to solve them simultaneously, without the aid of the airline schedulers, is not feasible.

The scheduling committees solve this problem by having the people who represent the airlines be those who have the ability and the authority to make on-the-spot changes in the schedules (sometimes after a phone call to higher company officials).

The committee process consists of a sequence of proffered concessions (consisting of a reduction in the number of slots requested or a "slide" of a requested slot from one hour to the next). Eventually these concessions yield a solution that is acceptable to all the members. However, it could well be that had a different sequence of concessions been followed, a solution would have developed that would have been preferable to all.

Most of the participants come to the scheduling committee meetings with at least a very good idea of what concessions they would be willing to offer. But these are never revealed until necessary.

The administrative procedure requires that each airline submit a number of slot plans (slots requested by hour). The airline can place a value on each plan to indicate its relative desirability. The procedure then looks through all possible combinations of these plans to find a set of plans that meet the requirements and is most satisfactory overall. It may be that no feasible set of plans can be found, in which case more alternatives must be provided.

The assignment of slots by hour is described in detail in Appendix B. The administrative procedures are described in more detail in Section II and sample problems are shown in Sections III and IV.

SECTION II

PROCEDURES

The following discussion describes the administrative procedures.

General Procedures

The airlines will submit initial slot requests for each hour of each day as they now do for the scheduling committees. These submissions will be tabulated and the results returned to the airlines. The tabulations will reveal where requests exceed hourly quotas. Based on these tabulations, some airlines might wish to reexamine their tentative schedules and unilaterally reduce or eliminate some of the conflicts. A second submission will allow any airline to revise its initial submission. All airlines will receive a copy of the revised tabulation.

It may be that a resolution is reached through this process. If so, there is no need for an administered allocation. (By resolution, it is meant that the number of slots desired does not exceed the quota in any hour.)

If more than one airport requires an administered allocation, those airports will be ranked in order of problem severity and resolved in order of decreasing severity. The measure of severity is the number of hours during which demand for slots exceeds the quota. After each airport is resolved, the airlines will be informed of the slot assignments and will be invited to revise their submissions for the next airport to reflect any necessary schedule changes.

For each airport requiring an administration of slots, each airline will submit the following data:

1. Its current allocation of slots at the airport (slots actually used).

2. The current average number of passengers enplaned or deplaned per operation (takeoff or landing) during the quota period at the airport.

3. A list of airports provided non-stop service to (or from) the airport in question in its current schedule.

Each airline will be allocated a total number of slots, Z_i, for the day. This will be decided on the basis of current share of slots, passengers served, and cities served. This number will not exceed the number requested on its final submission. Note that the passenger service is based on current schedules and not those being

developed. However, the airlines must consider these rating factors if they wish to maintain or increase their allocation on the next round.

The airlines will next submit a number of alternative hour-by-hour slot plans that do not exceed their total allocation of slots. The number of plans required and the requirements for their acceptance will be specified by the administering authority. Each airline will assign a value (from 0.0 to 1) to each plan to indicate its own relative preferences. This will be considered in the search for combinations that yield resolution. Each airline will also be given a weighting factor (to be defined later) that will be considered during this search. If several combinations of plans yield resolution, the final assignment will be selected based on the weighted airline preferences.

If no combination of plans submitted by the airlines yields resolution, additional plans will be requested. These plans might be subject to additional restrictions as described later. If there is no other way to achieve resolution, slot requests will be deleted, based on airline ranking factors, until resolution is achieved.

In general, there may be several hours in which slots are still available. These will be given to airlines that request them, with priority given to airlines that were least successful in achieving their slot preferences. Likewise some airlines may find that they cannot use some of the slots they have been assigned. These must be turned back in for possible reassignment to other airlines.

Procedures for New Entrants

The allocation procedure is based on the service currently being supplied at the airport. A new entrant does not have such a service history. Therefore, each new entrant will receive an initial four slots (granted as exemptions). If the planning period is one year in advance of the base period instead of six months in advance, the new entrant will still be a new entrant on the subsequent round and will still be given exempted slots because it was not an incumbent during the base period.

When the period comes when the airline was an incumbent in the base period, its slots are considered in the base and its performance with these slots is considered in allocating any additional slots. In this way it can continue to build its share of slots over subsequent periods.

Allocation Floor

Each airline will be granted a minimum of four slots. If the allocation procedure produces a value of fewer than four slots for

any airline, then the difference will be granted as exempted slots and the allocation procedure will be rerun.

Special Service Exemptions

It may be that an airline qualifies for guaranteed slots for special service needs. This might include airlines serving impacted markets and foreign flag carriers. They will be granted the required slots as exemptions, but with a difference--the special service exemptions will not be considered in the slot base on future rounds.

SECTION III

SAMPLE ADMINISTRATIVE ALLOCATION

Methodology

The allocation methodology consists of three functions:

1. An entitlement formula to determine how many slots each airline is entitled to.

2. A redistribution of slots between airlines when the entitlement exceeds airline requests.

3. A computation of a "fair share" of slots for each airline (proportional to the entitlement) for use during the assignment phase.

The entitlement function is similar to, but not identical to, the simple form presented in Section I. A precise definition is presented in Appendix A. When there are no exempted slots, the two versions are equivalent.

Sample Allocation

The allocation procedure was exercised on a hypothetical allocation of certificated air carrier slots at Washington National for the winter schedule in 1979. The base period data are somewhat mixed; data conveniently at hand were used. In particular, the slot allocation was based on the allocation actually in place while the winter allocation was being decided. In this case, statistics would be based on a comparable period (probably the winter schedule during the previous year).

The allocation was performed twice. Two different sets of weighting factors were used as shown in Table 3-1.

Table 3-1

Allocation Factors

Factor	Allocation 1	Allocation 2
R	0.50	0.50
P	0.30	0.35
C	0.20	0.15

The first hypothetical allocation is shown in Figure 3-1. There were 608 slots currently allocated and 640 slots were to be allocated. There were four carriers that are new entrants (as certificated carriers): Altair, Republic, Western, and Aeromech.

The column headed "SLOT CURR" shows the current allocation. It is assumed that these slots were actually used by the airlines. If not, a smaller value would be used. A value of zero designates a new entrant.

The column headed "SLOT REQT" shows of slots requested by the airlines. This was taken from the slot submissions filled out in advance of the winter scheduling committee meetings. Some airlines actually ended up getting more slots than was shown on the submission, and in these cases, the larger number was used.

The column headed "SLOT EXMP" indicates the exempted slots, or slots awarded outside of the entitlement formula. Each new entrant was given four slots as an exemption.

The column headed "E+D/PORTN" is the average enplanements and deplanements per operation. This is based on 1978 CAB data, except for Air Florida, New Haven and Empire for which data were not available. Assumed values were used for those airlines.

The column headed "APTS SRVD" is the number of different airports served, which was obtained from the OAG for May 1979.

The values discussed up to this point were input data to the computer program; the remaining values were computed. The computer program constructs a figure of merit ("FIGURE MERIT"), which (using terms introduced in Section I) is defined as:

$$f_i = \left[P(c_i e_i / \Sigma c_i e_i) + C (h_i / \Sigma h_i)\right] / (1-R)$$

It also computes a base number of slots "SLOT BASE" which is given by the current (non-exempted) slots times R, plus any exempted slots. In this example, the base consists of 304 slots (half the number of the current slots) plus 16 exempted slots for a total of 320 slots out of 640 to be allocated.

The remaining slots are distributed among the airlines in proportion to the figure of merit. Each airline gets additional slots ("SLOT DLTA") given by f_i times 320.

The sum of the base and additional slots forms a raw allocation ("RAW ALLOC") which each airline is entitled to. This divided by 640 forms the airlines fair share of slots. However, some airlines might request fewer slots than they would be entitled to. The excess is redistributed among airlines receiving fewer slots than requested in proportion to their fair share. This forms an adjusted allocation ("ADJD ALLOC").

FAA RUNWAY SLOT ALLOCATION PROGRAM

WASH. NATIONAL WKDAYS DEC. 79

640 SLOTS AVAILABLE — 17 AIR CARRIERS
ALLOCATION FACTORS: .500 FOR CURRENT SHARE
.300 FOR PASSENGERS SERVED
.200 FOR AIRPORTS SERVED

ALLOCATION TABLE

***	AIRLINE	SLOT CURR	SLOT REQT	SLOT EXMP	E+D / OPRTN	APTS SRVD	FIGUR MERIT	SLOT BASE	SLOT DLTA	RAW ALOC	FAIR SHARE	ADJD ALOC
1	AMERICAN	62	66	0	70.3	7	.096	31	31	62	.097	64
2	ALLEGHENY	72	82	0	50.0	11	.100	36	32	68	.106	70
3	BRANIFF	24	34	0	51.5	6	.043	12	14	26	.041	28
4	DELTA	34	36	0	88.5	2	.055	17	18	35	.055	36
5	EASTERN	142	142	0	64.5	19	.220	71	70	141	.220	142
6	NATIONAL	36	44	0	58.5	7	.061	18	19	37	.058	38
7	NORTHWEST	42	42	0	70.8	5	.067	21	21	42	.066	42
8	PIEDMONT	72	68	0	46.8	17	.121	36	39	75	.117	68
9	TRANSWORLD	44	58	0	81.6	6	.080	22	26	48	.075	50
10	UNITED	66	70	0	68.6	14	.127	33	41	74	.116	70
11	AIR FLA.	6	10	0	45.0	2	.012	3	4	7	.011	8
12	NEW HAVEN	4	8	0	10.0	1	.005	2	1	3	.005	4
13	EMPIRE	4	4	0	10.0	3	.013	2	4	6	.009	4
14	ALTAIR	0	8	4	0.	0	0.	4	0	4	.006	4
15	REPUBLIC	0	4	4	0.	0	0.	4	0	4	.006	4
16	WESTERN	0	4	4	0.	0	0.	4	0	4	.006	4
17	AEROMECH	0	12	4	0.	0	0.	4	0	4	.006	4
***	**********	****	****	****	*****	****	*****	****	****	****	*****	****
	TOTAL	608	692	16	63.0	100	1.000	320	320	640	1.000	640

Figure 3-1 Hypothetical Allocation for National Airport - Case I

The computations described produce non-integers. These are rounded to integers in the computer in such a way that the proper sum is maintained and the relative size of the fractional part is considered in determining which number among several is rounded up or down. The final allocation was also forced to be an even integer (a program option). (Note: if the allocation covers the entire day each airline must receive an even number of slots because each flight in is linked to a flight out.)

Based on this set of weighting factors, three airlines are entitled to more slots than they had requested: Peidmont, United and Empire. Their advantage, in each case, is a relatively large number of cities served relative to the number of slots currently held.

Figure 3-2 shows the second allocation which is based on identical input data, except for the weighting factors. (Less weight is placed on the number of airports served and more weight is placed on passengers served.) The result is the same except for four carriers that either gain or lose two slots each compared to the first allocation.

The following airlines could have received more slots than they had requested: Delta, Eastern, Northwest, Piedmont, Trans World, and Empire. The advantages these airlines have is mixed. Delta and Trans World have a very large number of enplanements and deplanements per operation compared to the others. Eastern has a better than average score on both measures.

The above observations indicate that the second set of weighting factors strike a more even balance between the two objectives. For that reason, the second set might be preferred. This is only the case for this particular problem. The particular choice of weighting factors, or a criterion for making that choice, is still open for discussion.

Table 3-2 shows the two hypothetical administered allocations and the actual allocation derived by the committee process. For the most part, the differences are relatively slight and this is due in part to the limited requests.

Passenger and Airline Impacts

In order to compare the impacts on air service and airline revenues, certain data had to be estimated. Table 3-3 shows a set of airline statistics that were inferred from data that were available. Operating profits per operation were estimated by J. Watson Noah and Associates from published load factors, fares, fees, and operating cost data. These data are very questionable for certificated commuters, but their relative contribution to the total is small anyway. Operating profits do not consider fixed overhead costs such

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ALLOCATION TABLE

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1	AMERICAN	62	66	0	70.3	7	.101	31	32	63	.098	66
2	ALLEGHENY	72	82	0	50.0	11	.099	36	32	68	.106	70
3	BRANIFF	24	34	0	51.5	6	.041	12	13	25	.039	26
4	DELTA	34	36	0	88.5	2	.061	17	20	37	.058	36
5	EASTERN	142	142	0	64.5	19	.224	71	72	143	.223	142
6	NATIONAL	36	44	0	58.5	7	.060	18	19	37	.058	38
7	NORTHWEST	42	42	0	70.8	5	.069	21	22	43	.067	42
8	PIEDMONT	72	68	0	46.8	17	.113	36	36	72	.112	68
9	TRANSWORLD	44	58	0	81.6	6	.084	22	27	49	.077	52
10	UNITED	66	70	0	68.6	14	.125	33	40	73	.114	70
11	AIR FLA.	6	10	0	45.0	2	.011	3	3	6	.009	6
12	NEW HAVEN	4	8	0	10.0	1	.004	2	1	3	.005	4
13	EMPIRE	4	4	0	10.0	3	.010	2	3	5	.008	4
14	ALTAIR	0	8	4	0.	0	0.	4	0	4	.006	4
15	REPUBLIC	0	4	4	0.	0	0.	4	0	4	.006	4
16	WESTERN	0	4	4	0.	0	0.	4	0	4	.006	4
17	AEROMECH	0	12	4	0.	0	0.	4	0	4	.006	4
***	**********	****	****	****	*****	****	*****	****	****	****	*****	****
	TOTAL	608	692	16	63.0	100	1.000	320	320	640	1.000	640

Figure 3-2 Hypothetical Allocation for National Airport - Case 2

TABLE 3-2

SLOT ALLOCATION FOR DECEMBER, 1979

Airline	Committee Actual*	Hypothetical Allocation 1	Hypothetical Allocation 2	Actual Requested
American	60	64	66	66
Braniff	24	28	26	34
Delta	34	36	36	36
Eastern	136	142	142	142
National	36	38	38	44
Northwest	40	42	42	42
Trans World	56	50	52	58
United	64	70	70	70
Western	4	4	4	4
U. S. Air	82	70	70	82
Piedmont	68	68	68	68
Air Florida	8	8	6	10
Republic	4	4	4	4
Altair	8	4	4	8
Aeromech	6	4	4	12
New Haven	6	4	4	4
Empire	4	4	4	4
Total	640	640	640	688

*Note: Three additional slots were actually awarded in the 0600 hour but these are not included because they were not contested.

TABLE 3-3

AIRLINE STATISTICS (ESTIMATED)

(Average Per Operation)

Airline	Operating Profit	E+D Passengers	Cities Served
American	$4,138	70.3	.112
U. S. Air	1,942	50.0	.153
Braniff	2,532	51.5	.250
Delta	4,214	88.5	.059
Eastern	3,426	64.5	.134
National	3,932	58.5	.194
Northwest	2,195	70.8	.119
Piedmont	1,608	46.8	.236
Trans World	3,188	81.6	.136
United	2,978	68.6	.212
Air Florida	2,950	45.0*	.333
New Haven	450*	10.0*	.250
Empire	450*	10.0*	.750
Altair	450*	10.0*	0.333*
Republic	2,540	50.0*	0.250
Western	2,848	50.0*	0.250
Aeromech	450*	10.0*	0.333*

*Assumed value for the purpose of this analysis.

as ticketing, baggage handling, rent, taxes, promotion, support staff, etc., and should not be used infer overall airline profitability.

Enplaned and deplaned passengers per operation were based on published reports for 1978. For airlines for which no data exist, assumptions were made. The number of different cities served by direct flight divided by the number of operations were based on OAG data. This was a problem for certificated commuters because it is impossible to tell from the data immediately available which service was provided by certificated airline slots and which was provided by commuter slots.

Table 3-4 shows estimated values for the committee allocation based on the data in Table 3-3. It was assumed that the total operating profit, total enplanements and deplanements, and total number of cities served can be computed by simply multiplying the estimated current averages by the number of operations. This is highly questionable in each case, but anything much more sophisticated would require information that is not available. These figures provide order-of-magnitude estimates that are suitable for comparison purposes.

According to Table 3-4, the airlines would obtain an operating profit of $1.8 million (excluding fixed costs) and enplane and deplane 39,415 passengers each day. The number of cities provided direct service contains one decimal place for comparative purposes. The total is merely the total of the column and should not be interpreted as 108 cities served because there is much duplication between airlines.

Table 3-5 shows the estimated values for the first administrative allocation. The airlines make an operating profit of $1.88 million and enplane and deplane 39,967 passengers each weekday. Both of these figures show a modest increase over the committee allocation. The surprise is that the number of cities served decreases, even though that was supposed to be a major consideration in the administered allocation. The reason for this is that the new entrants were allocated four slots each by exemption. The committee allocated to two of these airlines an additional 6 slots. These two airlines (Altair and Aeromech) were assumed to have a higher than average value of cities served per slot (due to their small number of slots) compared to the airlines that hold the great bulk of the certificated slots. Since these airlines were new entrants, the value of cities served per slot was used only in evaluating the allocation, not in making it. Had they been incumbents, they would have received more slots. But the assumption that they would actually expand the locations served in proportion to their slots is extremely questionable.

TABLE 3-4

EVALUATION OF COMMITTEE ALLOCATION

Airlines	No. of Slots	Operating Profit (000)	E+D Passengers	No. of Cities
American	60	$248.3	4,218	6.7
U. S. Air	82	159.2	4,100	12.5
Braniff	24	60.8	1,236	6.0
Delta	34	143.3	3,009	2.0
Eastern	136	465.9	8,772	18.2
National	36	141.6	2,106	7.0
Northwest	40	87.8	2,832	4.8
Piedmont	68	109.3	3,182	16.0
Trans World	56	178.5	4,570	7.6
United	64	190.6	4,390	13.6
Air Florida	8	23.6	360	2.7
New Haven	6	2.7	60	1.5
Empire	4	1.8	40	3.0
Altair	8	3.6	80	2.7
Republic	4	10.2	200	1.0
Western	4	11.4	200	1.0
Aeromech	6	2.7	60	2.0
Total	640	1,841.3	39,415	108.3

Note: The totals are estimates for 640 operations. Actual totals would also include operations not included here--principally, extra sections, which are not subject to the quota.

TABLE 3-5

EVALUATION OF ADMINISTERED ALLOCATION NO. 1

Airline	No. of Slots	Operating Profit(000)	E+D Passengers	No. of Cities
American	64	$264.8	4,499	7.2
U.S. Air	70	135.9	3,500	10.7
Braniff	28	70.9	1,442	7.0
Delta	36	151.7	3,186	2.1
Eastern	142	486.5	9,159	19.0
National	38	151.7	2,223	7.4
Northwest	42	92.2	2,974	5.0
Piedmont	68	109.3	3,182	16.0
Trans World	50	159.4	4,080	6.8
United	70	208.5	4,802	14.8
Air Florida	8	23.6	360	2.7
New Haven	4	1.8	40	1.0
Empire	4	1.8	40	3.0
Altair	4	1.8	40	1.3
Republic	4	10.2	200	1.0
Western	4	11.4	200	1.0
Aeromech	4	1.8	40	1.3
Total	640	1,883.3	39,967	107.3

Table 3-6 shows the estimated values of the second administrative allocation. Here more weight was given to passengers served (which tends to increase profitability) and less emphasis is given to locations served (which tends to decrease profitability). The result is an additional increase in estimated passengers served and profitability, and an additional decrease in cities served.

Comparing the second administrative allocation to the committee allocation shows a projected increases in operating profit of about $46,000 per weekday even though profit maximization was not one of the objectives, but is presumably an objective of the current system. What is shown here is that the scheduling committees, in order to get unamious agreement, can grant allocations that do not maximize overall profit. On the balance, the results indicate that the airlines might, in the aggregate, make more money (an increase of as much as $12 million per year) serve more passengers (as many as 438,000 per year), and serve at most two fewer cities.

It should be emphasized that the decrease in the projected number of cities served is not due to the logic of the model, but due to a questionable value of cities served per slot attributed to the exempted new entrant's slots--a value not provided to the program but only used to evaluate the allocation produced by the model.

It should also be emphasized that this sample allocation is for illustrative purposes only and was based on some out-dated and some assumed data. An allocation based on actual, current data could be somewhat different. The projected changes in airlines profitability and passengers service are merely linear projections based on current averages and are likely to be on the high side.

TABLE 3-6

EVALUATION OF ADMINISTERED ALLOCATION NO. 2

Airline	No. of slots	Operating Profit (000)	E+D Passengers	No. of Cities
American	66	$273.1	4,640	7.4
U. S. Air	70	135.9	3,500	10.7
Braniff	26	65.8	1,339	6.5
Delta	36	151.7	3,186	2.1
Eastern	142	486.5	9,159	19.0
National	38	151.7	2,223	7.4
Northwest	42	2.2	2,974	5.0
Piedmont	68	109.3	3,182	16.0
Trans World	52	165.8	4,243	7.1
United	70	208.5	4,802	14.8
Air Florida	6	17.7	270	2.0
New Haven	4	1.8	40	1.0
Empire	4	1.8	40	3.0
Altair	4	1.8	40	1.3
Republic	4	10.2	200	1.0
Western	4	11.4	200	1.0
Aeromech	4	1.8	40	1.3
Total	640	1,887.0	40,078	106.6

SECTION IV

SAMPLE ADMINISTRATIVE SLOT ASSIGNMENT

ASSIGNMENT METHODOLOGY

As mentioned in an earlier section, each airline is allocated a total number of slots for the day. It then submits alternative plans that show how it would like them distributed by hour. With each plan, is associated a value V(i,p), where i designates the index of the airline. The value is used to show the airlines preference for the alternative plans and ranges between 100 (for the most prefered plan) to 1. These preference values are used in developing a consolidated plan that allocates slots by hour to the airlines.

The assignment methodology has been automated. The computer program performs two functions:

1. A feasibility check to determine if a feasible solution exists. A feasible solution is a set of plans, one from each airline, such that; 1) there is one plan from each airline's list of plans, and 2) the total slots each hour do not exceed the quota. The feasibility check is performed for each hour. It consists of looking through each airline's plans, extracting the minimum request for the hour, summing over all airlines, and comparing the sum of minimums to the quota for the hour. If the sum exceeds the quota in any hour, the check fails.

2. A search routine (excuted if the feasibility check passes) that finds the best solution, if one exists. It may be that none exist, in which case that fact is uncovered. If more than one solution exists, the routine will produce the first solution that it finds, and then every solution that if finds that is better. The last solution printed (if any) is the best.

   The "best" solution is defined as the solution that maximizes the sum:

$$\sum_i w_i V(i,p)$$

Where:

wi = Airline weight = Nsi/Zi
N = Number of slots allocated
si = Airline's fair share of slots (fraction)
Zi = Number of slots allocated to airline i

This function: 1) values solutions that use the most prefered plans, and 2) values solutions that use the more prefered plans from airlines that have received fewer slots compared to what they were entitled to than other airlines.

SAMPLE PROBLEM

In February 1980, the Office of Aviation Policy conducted an experiment using these procedures. A number of airline employees with airline scheduling experience participated. The experiment involved a set of five hypothetical airlines (BL, GL, GR, RD, and WT) "run" by teams of participants and a hypothetical network of 16 airports. Three of these airports had quotas (Airport AAA, Airport BBB, and Airport CCC). Airport AAA and Airport BBB were easily resolved.

Airport CCC was very difficult to resolve. There were 18 hours in the day during which operations were simulated. A quota of 11 slots was established for the entire day (for a total 198 slots). Demand for slots was slight for three of the hours hence an allocation was made for 15 hours (165 slots) with the understanding that slots could be obtained in the other three hours in addition to those allocated. Therefore, the allocation was not restricted to even integers.

The allocation table is shown in Figure 4-1. Note that the number of base slots is 180, not 165. This is because the base was an allocation that was not quota-constrained.

The airlines then submitted their alternative slot plans. The initial set of slot plans did not pass the feasibility check. The airlines were told for what hours the feasibility check failed and were asked to submit additional plans to provided more flexibility in those hours. The result was the set of plans shown in Figure 4-2.

Figure 4-2 was produced by the program and is a restatement of the input data. Each row shows an alternative plan submitted by one of the airlines. The columns show (reading from left to right): 1) the airline, 2) a sequence value for the plan, 3) the value of the plan, 4) the airline weight, 5) slots requested each hour, and 6) the sum of all slots requested.

Below the list of slots submitted is a row showing the total minimum request for each airline summed over all airlines (the sum in the feasibility check). The line below that shows the quota for each hour. It can be seen that the feasibility check passed because there is no hour for which the total minimums exceed the quota.

However, it can be seen that no solution was found because the words "no more solutions" follow without any solution shown. One reason why no solution exists even though the feasibility check passes can be seen in the plans submitted by airline WT. Looking at the hours 0900 and 1000, one finds:

FAA RUNWAY SLOT ALLOCATION PROGRAM

CCC SLOT EXPERIMENT ROUND 1 HOURS 7-21

165 SLOTS AVAILABLE 5 AIR CARRIERS
ALLOCATION FACTORS: .500 FOR CURRENT SHARE
.350 FOR PASSENGERS SERVED
.150 FOR AIRPORTS SERVED

ALLOCATION TABLE

***	AIRLINE	SLOT CURR ****	SLOT REQT ****	SLOT EXMP ****	E+D / OPRTN *****	APTS SRVD ****	FIGUR MERIT *****	SLOT BASE ****	SLOT DLTA ****	RAW ALOC ****	FAIR SHARE *****	ADJD ALOC ****
1	BLUE	40	29	0	87.4	5	.250	20	19	39	.236	29
2	GOLD	47	42	0	68.2	6	.245	23	19	42	.255	42
3	GREEN	45	48	0	72.3	5	.237	22	18	40	.242	46
4	RED	28	28	0	57.9	5	.146	14	11	25	.152	28
5	WHITE	20	20	0	50.0	6	.122	10	9	19	.115	20
***	**********	****	****	****	*****	****	*****	****	****	****	*****	****
	TOTAL	180	167	0	69.9	27	1.000	89	76	165	1.000	165

Fig. 4-1 Allocation Table

SLOT ASSIGNMENT PROGRAM
CCC -- TEST OF ADFM.PROC. -ROUND 1

ALTERNATE SLOT REQUEST PLANS

AIRLINE	PLAN	VALUE	WEIGHT	TIME PERIOD 0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	SUM
BL	1	100	1.34	0	2	0	3	2	1	2	0	3	3	3	2	2	1	2	3	0	0	29
BL	2	99	1.34	0	2	1	2	2	1	2	1	2	3	3	2	2	1	2	3	0	0	29
BL	3	98	1.34	0	2	0	3	2	1	2	0	3	3	2	3	2	1	2	3	0	0	29
BL	4	97	1.34	0	1	1	3	2	1	2	0	3	3	3	2	2	1	2	3	0	0	29
BL	5	96	1.34	0	2	0	3	2	1	2	0	3	3	3	2	1	2	2	3	0	0	29
BL	6	95	1.34	0	2	0	2	3	1	2	0	3	3	3	2	2	1	2	3	0	0	29
BL	7	2	1.34	0	2	0	2	3	1	2	0	3	3	3	2	2	1	2	3	0	0	29
BL	8	1	1.34	0	2	0	3	2	2	1	0	3	3	3	2	2	1	2	3	0	0	29
GL	1	100	1.00	1	1	4	4	1	1	3	4	4	1	3	2	5	4	4	0	0	0	42
GL	2	99	1.00	1	1	5	3	1	1	3	4	4	1	3	2	5	4	4	0	0	0	42
GL	3	97	1.00	1	1	4	4	1	1	4	4	3	1	3	3	4	4	4	0	0	0	42
GL	4	90	1.00	1	1	4	3	2	1	4	4	3	1	3	3	4	4	4	0	0	0	42
GL	5	80	1.00	1	1	4	4	1	1	4	4	3	2	2	3	4	4	4	0	0	0	42
GL	6	70	1.00	1	1	4	3	2	1	4	4	3	2	2	3	4	4	4	0	0	0	42
GL	7	60	1.00	1	1	4	4	1	1	4	4	3	1	3	4	3	4	4	0	0	0	42
GL	8	1	1.00	1	1	4	3	2	1	4	4	3	1	3	4	3	4	4	0	0	0	42
GR	1	100	.87	0	3	2	3	4	5	4	4	1	3	3	4	2	1	3	4	0	0	46
GR	2	8	.87	0	3	2	3	4	5	4	3	2	3	3	4	2	1	3	4	0	0	46
GR	3	7	.87	0	3	1	3	4	5	4	4	2	3	3	4	2	1	3	4	0	0	46
GR	4	6	.87	0	3	1	3	4	5	4	4	1	3	3	4	3	1	3	4	0	0	46
GR	5	5	.87	0	3	1	3	4	5	4	4	1	3	3	4	2	2	3	4	0	0	46
GR	6	4	.87	0	3	1	3	4	5	4	4	1	3	3	4	2	1	4	4	0	0	46
GR	7	3	.87	0	3	2	3	4	5	4	4	1	3	3	4	2	1	3	4	0	0	46
GR	8	2	.87	0	3	2	3	4	5	4	3	1	3	3	4	2	3	1	5	0	0	46
GR	9	1	.87	0	3	2	3	4	6	3	3	1	3	3	4	2	2	2	5	0	0	46
RD	1	100	.90	0	2	1	3	3	1	0	3	2	3	0	3	3	1	3	3	0	0	28
RD	2	99	.90	0	2	2	2	3	1	0	3	2	3	1	3	2	1	3	0	0	0	28
RD	3	98	.90	0	2	1	3	3	1	0	3	3	2	1	3	2	1	3	0	0	0	28
RD	4	97	.90	0	2	2	2	3	1	0	3	3	2	1	3	2	1	3	0	0	0	28
RD	5	96	.90	0	2	1	3	3	1	0	3	2	3	0	3	3	1	3	0	0	0	28
RD	6	2	.90	0	2	2	2	3	1	0	3	2	3	0	3	3	1	2	1	0	0	28
RD	7	1	.90	0	2	2	2	3	1	0	3	2	3	0	2	4	1	3	0	0	0	28
WT	1	100	.95	0	2	3	2	1	4	1	1	2	1	0	0	2	0	1	0	0	0	20
WT	2	99	.95	0	2	3	1	2	3	2	1	2	1	0	0	2	1	0	0	0	0	20
WT	3	4	.95	0	2	2	2	2	2	2	1	2	1	0	1	2	0	1	0	0	0	20
WT	4	3	.95	0	2	2	2	2	2	2	1	2	2	0	0	2	0	1	0	0	0	20
WT	5	2	.95	0	2	2	2	2	2	2	1	2	1	1	0	2	0	1	0	0	0	20
WT	6	1	.95	0	2	2	2	2	2	2	1	2	1	0	0	2	1	1	0	0	0	20
TOTAL MIN REQSTED				1	9	8	11	11	10	8	11	10	10	7	10	10	7	9	7	0	0	165
QUOTA RESTRICTION				11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	198
NO MORE SOLUTIONS																						

Fig. 4-2 Alternative Slot Plans

Plan No.	Hour 0900	1000
1	2	1
2	1	2
3	2	2
4	2	2
5	2	2
6	2	2
Min	1	1

The minimum requested in each hour is 1 slot. However, for any given plan at least one of these hours will require 2 slots. But the total minimums for those hours was exactly equal to the quota. The above example shows that the minimums were not attainable.

The airlines were asked to provide more flexibility in the hours during which the feasibility check just barely passed. For example, airline GL reduced one slot or all plan in the 0900 hour airline RD dropped a slot in the 1000 hour. The result was that there still were no feasible solutions.

At this point it was decided to relax the quota constraints find an unfeasible solution that met the quota in as many hours as possible. Figure 4-3 shows the revised plans and the relaxed quotas. Several solutions were found that violate the quota of 11 in at most five hours. The first four are shown in Figure 4-4.

This time the entire group of players was called in and a mock scheduling committee was held. Beginning with Solution 3, the players quickly agreed among themselves to a large number of "slides" (moving a requested slot to another hour). This led to a feasible solution shown in Figure 4-5. Deviations from Solution 3 are indicated.

CONCLUSION

The idea behind the assignment methodology is that for whatever choices it is given, it can look at all possible combinations at a reasonable cost. This would be impossible manually. The committee procedure leads sequentially to only one solution, which could very well be less satisfactory to all than others that might exist.

In the example shown here, the road to a feasible solution was so complex that it would have been unfeasible to wait until enough alternate plans were submitted until finally some combination would work. In the meantime, a lot of unnecessary alternatives would have been developed.

This might seem to be a failure for the administrative procedure. On the other hand, the administrative procedure produced a starting point from which a negotiated settlement could be quickly found. This exercise did show that provision should be made for interactive airline negotiations, if an administrative procedure were adopted.

SLOT ASSIGNMENT PROGRAM
CCC -- TEST OF ADMIN.PROC. -ROUND 1

ALTERNATE SLOT REQUEST PLANS

AIRLINE	PLAN	VALUE	WEIGHT	TIME PERIOD 0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	SUM
BL	1	100	1.34	0	2	0	3	2	1	2	0	3	3	3	2	2	1	2	3	0	0	29
BL	2	99	1.34	0	2	1	2	2	1	2	1	2	3	3	2	2	1	2	3	0	0	29
BL	3	98	1.34	0	2	0	3	2	1	2	0	3	3	2	3	2	1	2	3	0	0	29
BL	4	97	1.34	0	1	1	3	2	1	2	0	3	3	3	2	2	1	2	3	0	0	29
BL	5	96	1.34	0	2	0	3	2	1	2	0	3	3	3	2	1	2	2	3	0	0	29
BL	6	2	1.34	0	2	0	2	3	1	2	0	3	3	3	2	2	1	2	3	0	0	29
BL	7	1	1.34	0	2	0	3	2	2	1	0	3	3	3	2	2	1	2	3	0	0	29
GL	1	100	1.00	1	1	4	4	0	1	3	4	4	1	3	2	5	4	4	0	0	0	41
GL	2	99	1.00	1	1	5	3	0	1	3	4	4	1	3	2	5	4	4	0	0	0	41
GL	3	97	1.00	1	1	4	4	0	1	4	4	3	1	3	3	4	4	4	0	0	0	41
GL	4	90	1.00	1	1	4	3	1	1	4	4	3	1	3	3	4	4	4	0	0	0	41
GL	5	80	1.00	1	1	4	4	0	1	4	4	3	2	2	3	4	4	4	0	0	0	41
GL	6	70	1.00	1	1	4	3	1	1	4	4	3	2	2	3	4	4	4	0	0	0	41
GL	7	60	1.00	1	1	4	4	0	1	4	4	3	1	3	4	3	4	4	0	0	0	41
GL	8	1	1.00	1	1	4	3	1	1	4	4	3	1	3	4	3	4	4	0	0	0	41
GR	1	100	.87	0	3	2	3	4	5	4	4	1	3	3	4	2	1	3	4	0	0	46
GR	2	8	.87	0	3	2	3	4	5	4	3	2	3	3	4	2	1	3	4	0	0	46
GR	3	7	.87	0	3	1	3	4	5	4	4	2	3	3	4	2	1	3	4	0	0	46
GR	4	6	.87	0	3	1	3	4	5	4	4	1	3	3	4	3	1	3	4	0	0	46
GR	5	5	.87	0	3	1	3	4	5	4	4	1	3	3	4	2	2	3	4	0	0	46
GR	6	4	.87	0	3	1	3	4	5	4	4	1	3	3	4	2	1	4	4	0	0	46
GR	7	3	.87	0	3	2	3	4	5	4	4	1	3	3	4	2	1	3	4	0	0	46
GR	8	2	.87	0	3	2	3	4	5	4	3	1	3	3	4	2	3	1	5	0	0	46
GR	9	1	.87	0	3	2	3	4	6	3	3	1	3	3	4	2	2	2	5	0	0	46
RD	1	100	.90	0	2	1	3	3	1	0	3	2	3	0	3	3	1	3	0	0	0	28
RD	2	99	.90	0	2	2	2	3	1	0	3	2	3	1	3	2	1	3	0	0	0	28
RD	3	98	.90	0	2	1	3	3	1	0	3	3	2	1	3	2	1	3	0	0	0	28
RD	4	97	.90	0	2	2	2	3	1	0	3	3	2	1	3	2	1	3	0	0	0	28
RD	5	96	.90	0	2	1	3	3	1	0	3	2	3	0	3	3	1	3	0	0	0	28
RD	6	5	.90	0	2	1	3	2	1	0	3	2	3	0	3	3	1	3	0	0	0	27
RD	7	3	.90	0	2	1	3	2	1	0	3	2	3	0	3	3	1	3	0	0	0	27
RD	8	2	.90	0	2	2	2	2	1	0	3	2	3	0	3	3	1	2	1	0	0	27
RD	9	1	.90	0	2	2	2	2	1	0	3	2	3	0	2	4	1	3	0	0	0	27
WT	1	100	.95	0	2	3	2	1	4	1	1	2	1	0	0	2	0	1	0	0	0	20
WT	2	99	.95	0	2	3	1	2	3	2	1	2	1	0	0	2	1	0	0	0	0	20
WT	3	5	.95	0	2	4	1	1	4	1	0	3	1	0	0	2	0	1	0	0	0	20
WT	4	4	.95	0	2	2	2	2	2	2	1	2	1	0	1	2	0	1	0	0	0	20
WT	5	3	.95	0	2	2	2	2	2	2	1	2	2	0	0	2	0	1	0	0	0	20
WT	6	2	.95	0	2	2	2	2	2	2	1	2	1	1	0	2	0	1	0	0	0	20
WT	7	1	.95	0	2	2	2	2	2	2	1	2	1	0	0	2	1	1	0	0	0	20
TOTAL MIN REQSTED				1	9	8	11	9	10	8	10	10	10	7	10	10	7	9	7	0	0	163
QUOTA RESTRICTION				11	11	11	12	12	12	11	11	11	11	11	12	12	11	11	11	11	11	203

Figure 4-2 Revised Slot Plans

SOLUTION 1

AIRLINE	PLAN	VALUE	WEIGHT	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	SUM
BL	1	100	134.28	0	2	0	3	2	1	2	0	3	3	3	2	2	1	2	3	0	0	29
GL	4	90	90.16	1	1	4	3	1	1	4	4	3	1	3	3	4	4	4	0	0	0	41
GR	9	1	.87	0	3	2	3	4	6	3	3	1	3	3	4	2	2	2	5	0	0	46
RD	2	99	88.68	0	2	2	2	3	1	0	3	2	3	1	3	2	1	3	0	0	0	28
WT	2	99	93.93	0	2	3	1	2	3	2	1	2	1	0	0	2	1	0	0	0	0	20
TOTAL SLOTS			407.9	1	10	11	12	12	12	11	11	11	11	10	12	12	9	11	8	0	0	164

SOLUTION 2

AIRLINE	PLAN	VALUE	WEIGHT	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	SUM
BL	5	96	128.90	0	2	0	3	2	1	2	0	3	3	3	2	1	2	2	3	0	0	29
GL	4	90	90.16	1	1	4	3	1	1	4	4	3	1	3	3	4	4	4	0	0	0	41
GR	9	1	.87	0	3	2	3	4	6	3	3	1	3	3	4	2	2	2	5	0	0	46
RD	2	99	88.68	0	2	2	2	3	1	0	3	2	3	1	3	2	1	3	0	0	0	28
WT	2	99	93.93	0	2	3	1	2	3	2	1	2	1	0	0	2	1	0	0	0	0	20
TOTAL SLOTS			402.5	1	10	11	12	12	12	11	11	11	11	10	12	11	10	11	8	0	0	164

SOLUTION 3

AIRLINE	PLAN	VALUE	WEIGHT	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	SUM
BL	5	96	128.90	0	2	0	3	2	1	2	0	3	3	3	2	1	2	2	3	0	0	29
GL	4	90	90.16	1	1	4	3	1	1	4	4	3	1	3	3	4	4	4	0	0	0	41
GR	9	1	.87	0	3	2	3	4	6	3	3	1	3	3	4	2	2	2	5	0	0	46
RD	8	2	1.79	0	2	2	2	2	1	0	3	2	3	0	3	3	1	2	1	0	0	27
WT	2	99	93.93	0	2	3	1	2	3	2	1	2	1	0	0	2	1	0	0	0	0	20
TOTAL SLOTS			315.7	1	10	11	12	11	12	11	11	11	11	9	12	12	10	10	9	0	0	163

SOLUTION 4

AIRLINE	PLAN	VALUE	WEIGHT	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	SUM
BL	5	96	128.90	0	2	0	3	2	1	2	0	3	3	3	2	1	2	2	3	0	0	29
GL	8	1	1.00	1	1	4	3	1	1	4	4	3	1	3	4	3	4	4	0	0	0	41
GR	9	1	.87	0	3	2	3	4	6	3	3	1	3	3	4	2	2	2	5	0	0	46
RD	9	1	.90	0	2	2	2	2	1	0	3	2	3	0	2	4	1	3	0	0	0	27
WT	2	99	93.93	0	2	3	1	2	3	2	1	2	1	0	0	2	1	0	0	0	0	20
TOTAL SLOTS			225.6	1	10	11	12	11	12	11	11	11	11	9	12	12	10	11	8	0	0	163

Figure 4-4 Solutions

	Slots Assigned															
	Hour															
Air-line	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
BL	0	2	0	3	2	1	2	0	3	3	3	2	1	2	2	3
GL	1	1	4	3	1	1	4	4	2*	2*	3	3	4	4	4	0
GR	0	3	3*	2*	4	5*	3	4*	1	3	3	4	2	3	1	5
RD	0	2	2	2	2	1	0	3	2	2*	2*	2*	2*	2*	3	0
WT	0	3*	2*	1	2	3	2	0*	3*	1	0	0	2	0*	1*	0
Total	1	11	11	11	11	11	11	11	11	11	11	11	11	11	11	8

*Slot assignment differs from starting point

Figure 4-5 Slot Assignment--as Negotiated

SECTION V

CONCLUSION

This report presents an approach to the administrative assignment of runway slots. This method has been proposed for inclusion in a notice of proposed rule making on slot allocation at Washington National.

The advantages claimed for this system are:

1. It simulates to some extent the operations of the current scheduling committees so that it could be used to replace the scheduling committees (either temporarily or permanently) with relative ease.

2. It has as its objective improvement in passenger service both in number of passengers served per air carrier operation and in the number of locations served.

3. It is designed to produce only gradual changes in allocation of slots between airlines to avoid disruptive changes in service patterns.

4. It considers airline scheduling constraints by directly involving airline schedulers in the distribution of slots by airline by hour.

Although this procedure has been exercised on several sample problems it has not been tried in an actual situation. Several areas of further refinement will have to be worked out at that time. These includes:

1. A final determination of the values for the allocation weighting factors.

2. Final determination of the required number of alternative slot plans and of acceptance criterea for these plans.

3. What exactly to do if the alternative plans submitted do not yield resolution.

4. How to detect and prevent cheating the system (e.g., an airline requesting unwanted slots merely to prevent a competitor from getting them).

A simulated exercise carried out in February 1980 by the FAA, in cooperation with several leading airlines, revealed these questions and produced some solutions. It may be that in an actual situation these solutions might have to be modified somewhat.

This is not to say that the methodology is not ready for implimentation. It is only to say that these are issues that cannot be settled without actual experience and the initial implimentation may uncover the need for additional work in these areas that could be performed at that time.

APPENDICES

APPENDIX A

SLOT ALLOCATION PROGRAM

Two computer programs have been developed to perform the calculations described in the proceeding section. The process, both computationally and administratively, is divided into two stages: 1) the allocation of a number of slots to each airline for the day (or quota period during the day), and 2) the assignment of a number of slots to each airline for each hour. Each process might be repeated several times, with slight changes in the input data, until the desired results are obtained. Also, there will be some interaction between the administering authority and the airlines between the two stages. Therefore, it is necessary that the computer program for each stage be separate. This appendix describes the Slot Allocation Program.

Allocation Program Functions

The Allocation Program performs three functions:

1. It contains an "entitlement formula" to determine how many slots each airline is entitled to.

2. It redistributes slots between airlines when the entitlement exceeds airline requirements.

3. It computes the "fair share" of slots for each airline (similar to the entitlement) for use during the assignment phase.

In many cases, the number of slots requested for the entire quota period will not exceed the total available. Therefore, there is no allocation problem. However, the allocation program should still be run in order to generate the "fair share" values for use in the assignment phase. Also, the allocation program does not need to be run for the entire quota period. If there are several hours in which the numbers of slots requested is well below the quota, these hours could be removed from the problem and those slots granted manually.

DETAILED DESCRIPTION OF THE ALLOCATION PROCEDURE

The final submission will be used as a basis for determining the allocation of slots by day between airlines. The allocation will be performed for one typical day at a time. If the submissions vary significantly for different days of the week or for different weeks during the planning period (six months), then each such day will be allocated separately.

The procedures for the allocation are described mathematically below.

The following data are required:

N = Number of slots to allocate

I = Number of airlines

c_i = Current number of slots for airline i (including exempted slots, except for special service exemptions).

r_i = Number of slots requested by airline i on the submission (including exempted slots).

e_i = Average number of passengers enplaned or deplaned per scheduled operation during the quota period by airline i.

h_i = Current number of airports given direct service by airline i from (or to) the airport under consideration.

x_i = Number of slots granted as an exemption. Exemptions provide for: 1) special service authority, e.g., international agreements, 2) new entrants, and 3) providing a minimum number of slots to be awarded to each participating airline for airlines that otherwise would not obtain the minimum.

R, P, and C = Weighting factors, non-negative fractions that sum to 1.

The first step is to grant each incumbent airline a certain number of uncontested slots which consists of a similar percentage of its current slots and any exempted slots. This slot base is

$$b_i = Rc_i + x_i$$

R=0.5 is suggested, but this might be changed in the future, if need be. Note that incumbent airlines will generally receive significantly more than R times than current slots because the subsequent computations provide additional slots in a manner that considers the amount of service currently provided.

The next step is to allocate the remaining slots (contested slots) on the basis of passenger service. There are two measures of determining passenger service. One is the number of passengers served and the other is the number of different airports given non-stop service by the airline. The first is weighted by P and the second is weighted by C. Both depend of the number of slots currently allocated to the airlines (so that the increase or decrease in allocation is in relation to the airline's current level of operations). The precise method of computation is as follows:

A figure-of-merit, f_i, is computed for each airline based on its passenger service relative to the passenger service offered by the other airlines.

$$f_i = \left[P(c_i e_i / \Sigma c_i e_i) + C(h_i / \Sigma h_i) \right] / (1-R)$$

These are fractions between zero and one such that the sum over all airlines is one. Their values depend on the relative number of different airports and total passengers served by each airline. Extra sections do not require slots. Therefore, passengers on extra sections are not counted in the total but they are included in computing the average enplanement and deplanements per operation. The f_i depend indirectly on the current number of slots so that the new allocation will tend to be in proportion to the current allocation to the extent that passenger service per slot is equal between airlines.

The contested slots are allocated to each airline by:

$$d_i = f_i \, (N - \Sigma b_i)$$

A raw allocation, q_i, is the sum of the contested and uncontested slots.

$$q_i = b_i + d_i$$

The raw allocation is constructed in such a way that the quantities involved are non-negative integers and the sum of the q_i is N. However, some airlines might receive more slots than they have requested.

The final allocation, a_i, is made as follows:

1. If $q_i \geq r_i$ for all i, then $a_i = q_i$, for all i.

   I.e., if no airline receives more than it requested, the allocation stands.

2. If $\sum r_i \leq N$, then $a_i = r_i$, for all i.

   I.e., if the total number of slots requested is less than N, each airline is allocated the number requested.

3. Otherwise, $a_i = r_i$ for those i such that $q_i > r_i$ and the surplus is redistributed among the remaining airlines in proportion to their raw allocation.

The final allocation, a_i, is always restricted to integers. If the allocation period covers the whole day, the allocation is restricted to even integers.

In general, the raw allocation will exceed the requests for some airlines therefore, some airlines will receive more or less than their "fair share" of slots. This will also occur to the above-mentioned rounding procedures. A fair share, s_i, for each airline is recorded for use in the Assignment Program. This is a fraction between zero and one.

$$s_i = (1/N)\left\{Rc_i+x_i+\left[P(f_i/\Sigma f_i)+C(h_i/\Sigma h_i)\right](N-R\Sigma c_i-\Sigma x_i)/(1-R)\right\}$$

THE SLOT ALLOCATION PROGRAM INPUT PARAMETERS

Both programs are written in FORTRAN IV and are designed to be executed in a "batch mode" using punched cards (or a "card-image" on-line file). The input requirements and formats for the Slot Allocation Program are described below.

The input requirements and formats are listed in Table A-1. The first card contains a description (50-characters) provided by the user. The second card contains run parameters for the allocation: the number of slots, the number of airlines, the weighting factors, and the key indicating whether or not even number rounding is desired.

Only two of the three weighting factors are required. The third is computed by:

$$C = 1-R-P$$

Following this card is a set of cards, one for each of the airlines. The number of these cards must correspond to the number of airlines specified on the second card. This completes the data required for one allocation. If additional allocations are desired (for a different airport, different time periods, alternative values of input parameters, etc.) they can be run by simply adding cards following the same formats.

When all allocation problems have been added to the deck, they are followed by a blank card and then a card that contains zero in columns 5 and 10. This indicates that all the problem sets are completed.

TABLE A-1

INPUT FORMAT FOR SLOT ALLOCATION PROBLEM

CARD 1

Columns	Format	Item
1-50	A50	Problem label

CARD 2

Columns	Format	Item
1-5	I5	N = Number of slots to allocate
6-10	I5	I = Number of Airlines
11-15	F5.0	R = Weight for current slots
16-20	F5.0	P = Weight for enplanements and deplanements
21-25	I5	Round-off Key (2 = even integers only)

CARD-3, 4, 5,...,(one for each airline)

Columns	Format	Item
1-10	A10	Airline Name
11-15	I5	c_i = Current number of slots
16-20	I5	x_i = Number of exempted slots
21-25	I5	r_i = Number of slots requested
26-30	I5	h_i = Number of airports served
31-35	F5.0	e_i = Enplanements and deplanements per operation

SAME AS ABOVE - ADDITIONAL ALLOCATION PROBLEMS (IF ANY)

BLANK CARD
FINAL CARD

Column	Format	Item
5	I1	0
10	I1	0

APPENDIX B

SLOT ASSIGNMENT PROGRAM

THE ASSIGNMENT OF SLOTS BY HOUR

Each airline must submit a number of alternative distribution plans showing the assignment of its share of slots, by hour for each hour. The total slots in each plan must not exceed the number of slots allocated to the airline for the day, Zi.

The number of alternative plans required will be specified by the administering authority. Additional plans will aid in finding solutions and will be welcomed.

For each alternative plan, p, the airline supplies a value V(i,p) indicating its relative preference to the airline. These values should range between 100 and 1, where 100 is the value for the most preferred plan and 1 the value for the least preferred plan.

These values will be used to select from alternative combinations. Priority is given to higher-valued plans. If the airline is indifferent to two or more plans, they can be given the same value. If the airline strongly prefers one plan over another, the difference in values can be made large.

These plans are examined concurrently to determine if a combination of them yeilds a feasible solution. This is a set of plans, one for each airline, such that the total slots assigned in each hour does not exceed the quota for that hour.

A weighting factor is computed for each airline as follows:

$$w_i = (Ns_i/Zi)$$

which is the ratio of the airline's fair share of slots (not necessarily an integer) to the number allocated. This device gives preference in the selection of slot plans to those airlines that, either through limiting their requests or through rounding-off, have received fewer slots than they would have otherwise.

If more than one set of plans produces resolution, then that combination that maximizes the weighted sum.

$$\sum w_i V(i,p)$$

is selected.

If the initial set of plans does not lead to resolution, additional plans might be requested. These plans might be subject to additional restrictions, as follows:

1. In no overloaded hour should the number of slots to be assigned exceed the airline's overall proportion of slots by more than 10 percent rounded to the next highest integer. (An overloaded hour is defined as an hour in which no combination of existing plans will produce resolution. The hours that are overloaded will be determined by the administering authority.)

That is,

$$n(i,t) \leq \left\{ (1.1)Z_i q(t)/N \right\} \text{ (rounded up)}$$

where:

$n(i,t)$ = the number of slots requested by airline i for hour t

$q(t)$ = the hourly quota for hour t.

For example, if $q(t) = 40$, $Z_i = 60$, and $N = 550$, then the expression in the square brackets yeilds 4.8, which rounded-up yields 5. Thus, $n(i,t)$ must not exceed 5 for all overloaded hours.

2. Each plan must differ from each other plan in two or more overloaded hours.

If additional plans do not lead to resolution, the administering authority must take other means. This could include consultation with airlines individually or as a group, with the ultimate threat of administratively dictating slot assignments for problem hours in proportion to "fair share".

The Slot Assignment Program

The input requirements are listed in Table B-1. The final card contains the airport code and a run description to allow the user to label the output. The second card contains the number of time periods (usually hours), the number of airlines and control parameters.

As pointed out in the report, the number of hours need not coincide with the number of quota hours if allocation of slots is only a problem during a portion of the period. Likewise, the hourly quota can be less than the actual quota; if special exemptions are granted for particular slots they can be taken out of the problem.

If KHT is not equal to 1, a check is performed on the slot requests for each hour by each airline to insure that they do not request an inordinate number in any hour. If KMT equals 1, all feasible solutions are printed; if not, only those that have a higher value of the objective function than the last one printed will be printed.

TABLE B-1

INPUT FORMAT FOR THE SLOT ASSIGNMENT PROGRAM

CARD 1

Columns	Format		Item
1-3	A3		Airport Code
6-35	A30		Problem description

CARD 2

Columns	Format	Label	Item
1-4	I4	TBIG	No. of time periods (max. 19)
5-8	I4	KBIG	No. of Airlines (max. 20)
9-12	I4	KHT	Hourly requested checks? (1=No)
13-16	I4	KMT	All solutions? printed? (1=Yes)

CARD 3

Columns	Format	Label	Item
1-4	A4	LABT(1)	Lable of first time period
5-8	A4	LABT(2)	Lable of second time period
:	:	:	:
.	.	.	.
etc.	etc.	etc.	etc.

CARD 4

Columns	Format	Label	Item
1-4	A4	LABA(1)	Lable of first airline
5-8	A4	LABA(2)	Lable of second airline
:	:	:	:
.	.	.	.
etc.	etc.	etc.	etc.

CARD 5

Columns	Format	Label	Item
1-4	I4	Q(1)	Quota for first time period
5-8	I4	Q(2)	Quota for second time period
:	:	:	:
.	.	.	.
etc.	etc.	etc.	etc.

TABLE B-1 (Continued)

CARD 6

Columns	Format	Label	Item
1-4	I4	NC(1)	Number of slot plans for first airline
5-8	I4	NC(2)	Number of slot plans for second airline
:	:	:	:
etc.	etc.	etc.	etc.

CARD 7

Columns	Format	Label	Item
1-4	F4.4	W(1)	Fair share (fraction) for first airline
5-8	F4.4	W(2)	Fair share (fraction) for second airline
:	:	:	:
etc.	etc.	etc.	etc.

CARD 8

Columns	Format	Label	Item
1-4	I4	NZ(1)	Number of slots allocated for first airlines
5-8	I4	NZ(2)	Number of slots allocated for second airline
:	:	:	:
etc.	etc.	etc.	etc.

CARD 9, 10, 11...(one for each slot plan)

Column	Format	Label	Item
1-4	F4.4	VAL(I)	Value of slot plan
5-8	I4	RQ(1, 1)	Number of slots the first hour
9-12	I4	RQ(1, 2)	Number of slots for second hour
:	:	:	:
etc.	etc.	etc	etc.

The third card contains labels for the time periods. The fourth card contains labels for the airlines. The next cards contain the quota, by hour; the number of slot plans to be supplied, by airline; the fair share (a fraction between zero and one), by airline; and the number of slots allocated (Zi) for the hours to be assigned, by airline.

The remaining cards contain the slots plans (one plan per card). The plans are to be arranged by airline and in decreasing order of VAL within airline. The number of plans must correspond with the number specified on Card 6 for each airline and in that order.

Figure B-1 is a flow diagram of the Slot Assignment Program. The portion labeled "search for solutions" is diagramed in some detail in Figure B-2.

There is no provision for multiple executions of this program in one step.

Although a very large combination of plans exist, the program's feasibility check makes the process fairly efficient, especially when the option KMT $\neq$ 1 (only the best solutions are shown) is used. Use of this option is strongly recommended, except when the number of feasible solution is known to be quite small. Otherwise, a very large number of feasible solutions could be printed and the cost of the run become exhorbitant.

Since the plans are listed in decreasing order of value, the first solutions found are usually the best. Thus, the KMT $\neq$ 1 option results in only a few of the feasible solutions being printed and a very efficient search.

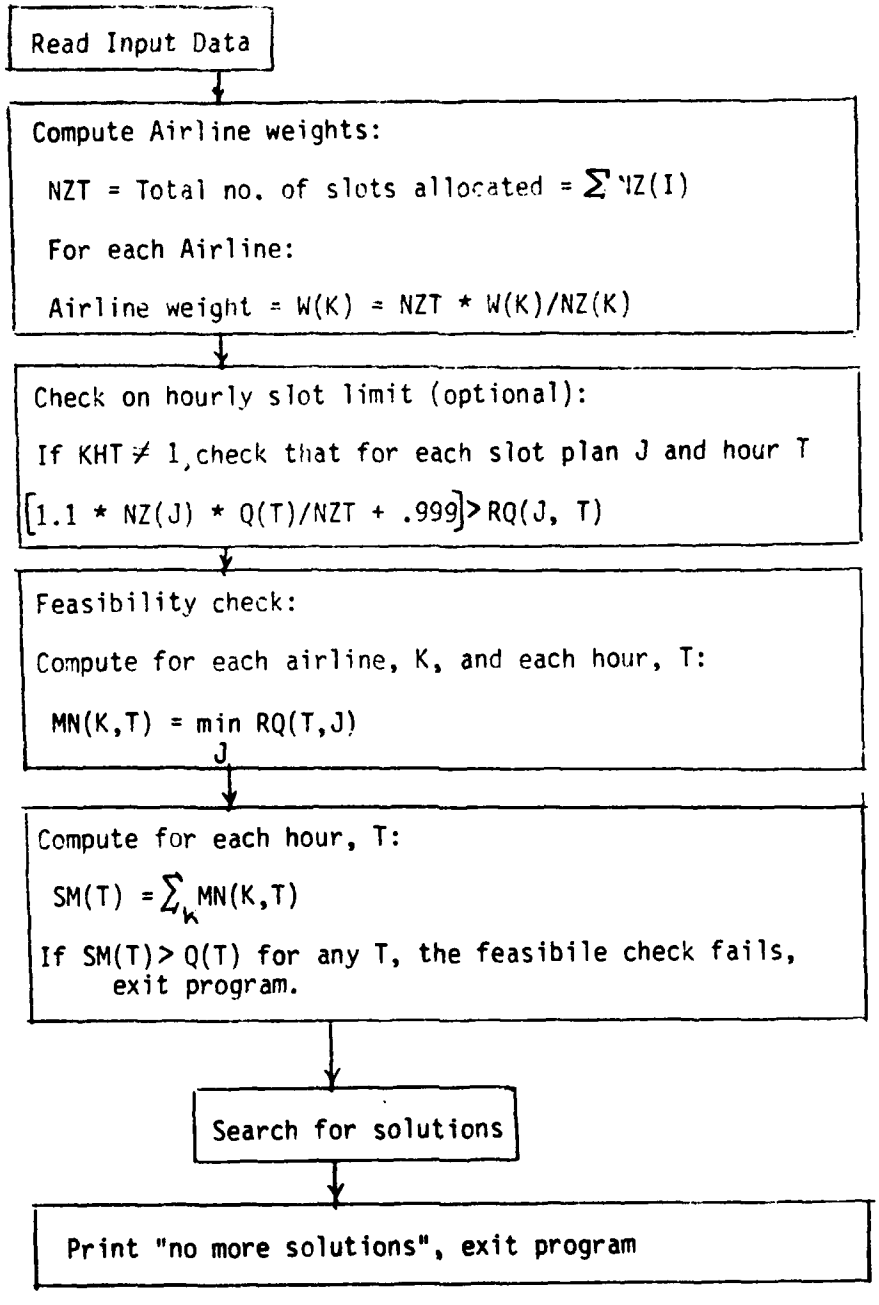

Figure B-1 Flow Diagram - Slot Assignment Program - Overview

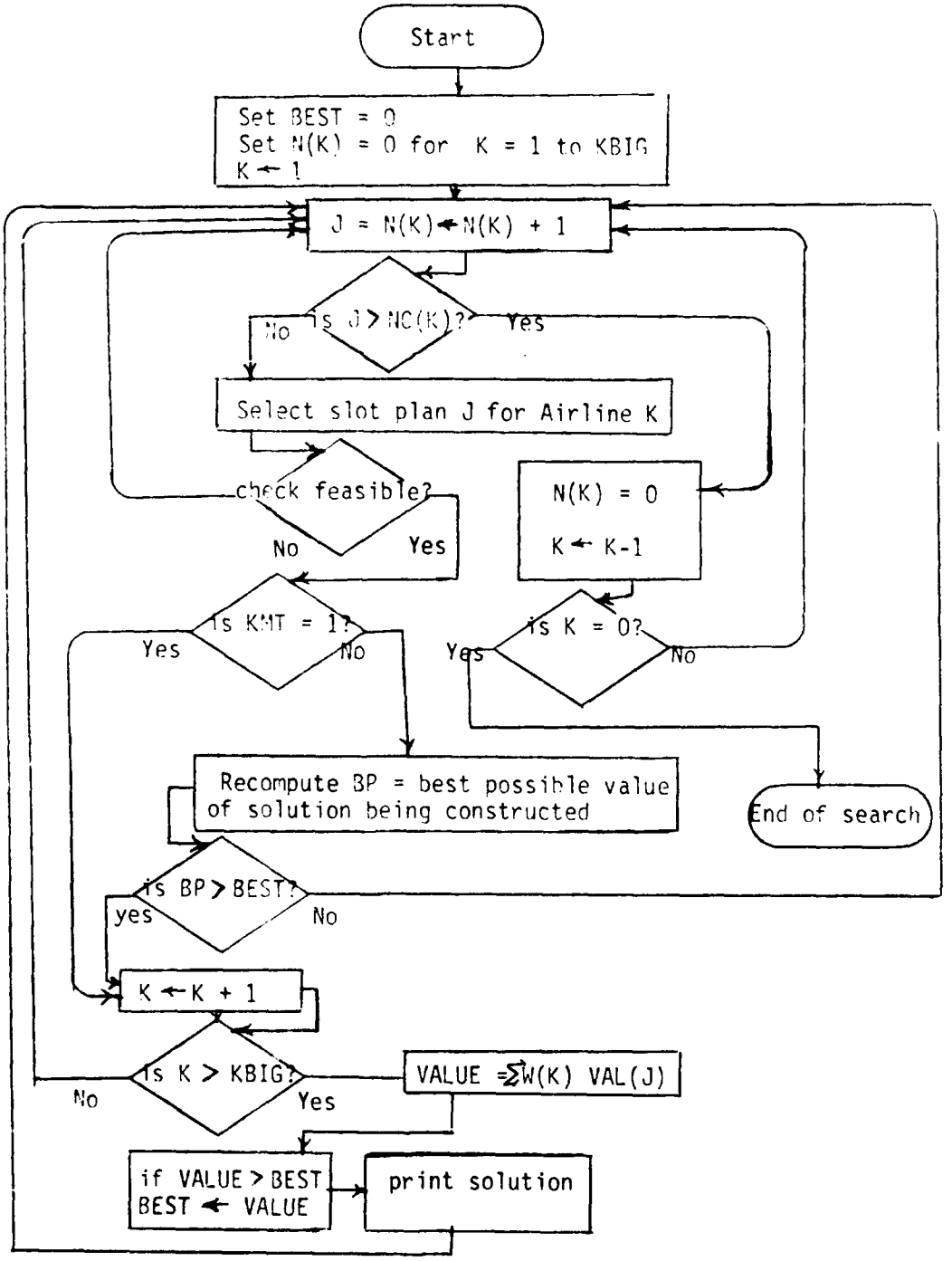

Figure B-2 Flow Diagram-Slot Assignment Program
Search for Solutions

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